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# ECOLOGICAL FACTORS IN NORTH TEXAS RELATED TO THE 1935 STEM RUST EPIDEMIC

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UNITED STATES DEPARTMENT OF AGRICULTURE

# ECOLOGICAL FACTORS IN NORTH TEXAS RELATED TO THE 1935 STEM RUST EPIDEMIC [1]

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## Introduction

Stem rust (Puccinia graminis tritici Eriks. and Henn.) is one of the most destructive and widespread diseases attacking the wheat plant. Official estimates of losses from stem rust in the United States may be obtained from various sources and will not be given here. The 1935 epidemic was one of the most destructive in history and extended over most of the wheat-growing areas of the United States.

The two wheat rusts, stem rust (Puccinia graminis tritici) and leaf rust (Puccinia triticina) are of major economic importance in Texas. These diseases limit the production of wheat in Texas to the more north-central parts of the State and to regions of lower rainfall in the western part, where rust usually is not a factor. The estimated annual loss from stem rust in Texas from 1925 to 1934 was 359,000 bushels, while that caused by leaf rust was 388,200 bushels [3]. Stem rust is every year a limiting factor in wheat production from central Texas southward. In north-central Texas the disease is present nearly every year, but often is not a major factor in yield because of the early maturity of the crop. Because of the extensive wheat acreage, however, this area serves as a breeding ground for stem rust and increases the inoculum to be carried northward as the season progresses. During mild winters stem rust may actually overwinter in this area.

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[1] A report of cooperative investigations between the Division of Cereal Crops and Diseases, Bureau of Plant Industry, United States Department of Agriculture, and the Texas Agricultural Experiment Station at Texas Substation No. 6, Denton, Texas.

[2] Thanks are due Mr. P. B. Dunkle, Superintendent of Substation No. 6, Denton, Texas, and the Texas Agricultural Experiment Station for permission to use unpublished meteorological data as given in this report.

[3] United States Department of Agriculture, Bureau of Plant Industry, Division of Mycology and Disease Survey, Plant Disease Reporter Supplements 49, 56, 64, 83, 87, and 89. Reports of losses from diseases in the United States for the years 1925 to 1934 inclusive.

Since the north Texas area is so important from a national standpoint in the early season development of an epidemic, any information relative to ecological factors previous and co-incident to the development of the 1935 stem rust epidemic in Texas is in turn related to the spread of the disease throughout much of the United States. Data on meteorological and ecological conditions in Texas as related to the 1935 stem rust epidemic are therefore presented.

## Epidemiology Of Stem Rust At Denton, Texas, In 1935

Stem rust was first observed at Texas Substation No. 6, Denton, Texas, on May 7. It is possible that there may have been some points of infection in North Texas prior to this time and perhaps even some overwintering in the area. General infection did not start until about this date. Previous to this time, as will be pointed out later, weather conditions were not favorable for the development and spread of the disease.

### Meteorological Factors Affecting The Stem Rust Epidemic

General Weather Conditions: All climatological data that might influence stem-rust infection and spread have been tabulated in Table 1. Data are given for the months of April, May, and June for the years 1931 to 1935 and averages for a 21-year period. Daily temperature and humidity for 1935 are presented in later tables and graphs. The rust data here presented are taken from the field-plat variety test of 18 varieties grown during the 5-year (1931-35) period.

Temperature: Numerous investigations have shown that temperature is one of the most important factors in the development and spread of a stem-rust epidemic. In the present study the mean daily temperature, as well as the morning temperature, has been considered. Data are presented in Figure 1 showing the daily mean temperature for the months of April, May, and June. This period includes the period from the booting stage of the grain until it is fully matured. Monthly mean temperatures for 1935 and for a 21-year period are shown for comparison.

The first stem rust was observed at Denton, Texas, on May 7, 1935. As the incubation period for stem rust varies from one to two weeks, it would have been necessary for the general infection to have taken place during the last week of April. Peltier [4], [5], [6], [7] and Stakman and Lambert [8] have shown that the optimum temperature for rust infection is about 68° F., although if there is free moisture and the humidity of the air is high, infection may take place at temperatures of 50° to 75° F. A study of Figure 1 shows that the mean daily temperature during the last week of April was favorable for rust infection. During the first week of May, temperatures were below normal and not so favorable for rust infection. Following this period, temperatures were favorable for rust infection and development throughout the remainder of the growing season. Detailed meterological data, including temperature, taken at the morning reading, are presented under a separate heading because of the importance of this period of the day in rust infection.

Humidity and Precipitation: Humidity is no doubt second only to temperature as a factor controlling the germination of rust spores and subsequent infection of the wheat plant. Since humidity and precipitation are often closely allied they will be considered together.

In Figure 2 the mean daily relative humidity for each day of the three-month period, April 1 to June 30, is shown. Precipitation during the period also is shown. Monthly precipitation compared with the normal was given in Table 1.

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[4] Peltier, George L. A study of the environmental conditions influencing the development of stem rust in the absence of an alternate host I. Nebr. Exp. Sta. Res. Bul. 22. 1922.

[5] Peltier, George L. A study of the environmental conditions influencing the development of stem rust in the absence of an alternate host II. Nebr. Exp. Sta. Res. Bul. 25. 1923.

[6] Peltier, George L. Relation of weather to the prevalence of wheat stem rust in Nebraska. Jour. Agr. Res. 46:59-73. 1923.

[7] Peltier, George L. Some aspects of the spread of stem rust. Zentralbl. Bakt. II Abt., 78:525-535. 1929.

[8] Stakman, E. C., and E. B. Lambert. The relation of temperature during the growing season in the spring wheat area of the United States to the occurrence of stem rust epidemics. Phytopathology 14:94-100. 1924.

Rainfall for the month of April was about normal in total amount but it all occurred after April 18. Previous to this there was a time interval in March and April when there was insufficient moisture for the crop. During that period conditions were not favorable for rust infection. After rains started in April, both humidity and temperature were favorable for rust infection and spread.

A total of 11.52 inches of precipitation was recorded during May, a record amount for that month. A measurable amount of precipitation occurred on 13 days of the month. This unusual amount of moisture promoted continued growth of the wheat crop for a longer than normal period, and thus delayed heading and maturity. Associated with the large amount of precipitation of May were extremely high relative humidity and subnormal temperatures. The mean daily humidity did not fall below 66 percent at any time during the month. The mean, 83.2 percent, for the month is 13.3 percent above normal. The conditions, therefore, were favorable for rust infection throughout the month.

Because of extremely late maturity of the crop, June weather was a factor in rust development this season, whereas, normally, it would not be. Precipitation in June was 5.27 inches compared with the normal of 2.85 inches. The relative humidity was never below 64 percent and the mean relative humidity of 77.[illegible] percent was 13.4 percent above normal.

From the above study of humidity and precipitation during the period when the wheat plants were susceptible to rust, it is evident that conditions were extremely favorable in 1935 for the development of a rust epidemic. The excessive precipitation and high humidity contributed much to the delay in ripening of the grain and thus furnished ample time for the epidemic to develop in northern Texas and provide inoculum for the continued spread of the disease in other states.

Temperature and Humidity at Time of the Morning Reading: Environmental factors are usually most favorable for rust infection early in the morning. Because of this it was considered desirable to study, in addition to mean daily temperatures and relative humidity, the temperature and humidity at the morning reading. This reading is taken at 7 o'clock. In Figure 3 the relative humidity and temperature at the morning reading for the period April 1 to June 30 are shown. Days on which dew occurred are shown also.

Previous to April 18 conditions were not very favorable for germination of rust spores. Temperatures were favorable on certain days, but often when the temperature was favorable, the humidity was fairly low. Dews also were less frequent than later in the season.

Table 1. Climatological data recorded at Texas Substation No. 6, Denton, Texas, for the years 1931 to 1935, inclusive, and averages 1914 to 1935.

| | 1931 | | | 1932 | | | 1933 | | | 1934 | | | 1935 | | | Average 1914-1935 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Apr. | May | June | Apr. | May | June | Apr. | May | June | Apr. | May | June | Apr. | May | June | Apr. | May | June |
| Mean maximum temperature | 71.9 | 78.5 | 93.7 | 78.7 | 81.9 | 90.8 | 79.4 | 84.6 | 93.7 | 76.3 | 84.8 | 97.6 | 75.7 | 77.0 | 87.1 | 76.0 | 81.0 | 91.8 |
| Mean minimum temperature | 47.4 | 55.2 | 68.6 | 52.0 | 59.7 | 68.9 | 50.5 | 63.5 | 66.2 | 54.4 | 60.0 | 71.9 | 51.6 | 59.0 | 66.4 | 51.8 | 59.9 | 68.8 |
| Mean monthly temperature | 59.7 | 66.8 | 81.2 | 65.4 | 70.8 | 79.8 | 64.9 | 74.1 | 80.0 | 65.6 | 72.4 | 84.8 | 63.7 | 68.0 | 76.8 | 63.9 | 70.8 | 80.1 |
| Mean relative humidity | 74.7 | 74.6 | 63.8 | 64.1 | 74.3 | 73.8 | 60.3 | 73.4 | 56.1 | 72.2 | 66.1 | 50.7 | 72.0 | 83.2 | 77.9 | 67.1 | 72.0 | 64.5 |
| Total evaporation-inches | 4.02 | 5.24 | 7.40 | 5.66 | 5.61 | 6.48 | 5.84 | 5.91 | 8.43 | 4.68 | 6.21 | 10.1 | 4.47 | 4.67 | 6.23 | 5.09 | 5.65 | 7.51 |
| Total precipitation-inches | 1.71 | 2.19 | 1.37 | 1.96 | 4.57 | 4.82 | 2.24 | 5.22 | .05 | 4.19 | 4.24 | .23 | 3.54 | 11.52 | 5.27 | 3.82 | 4.63 | 2.85 |
| Number days with .01 inch or more precipitation | 8 | 8 | 7 | 6 | 7 | 9 | 5 | 8 | 1 | 8 | 6 | 1 | 10 | 13 | 10 | 7.9 | 8.4 | 6.5 |
| Number of clear days | 12 | 14 | 15 | 16 | 16 | 14 | 16 | 16 | 28 | 12 | 21 | 30 | 13 | 11 | 14 | 13.7 | 14.6 | 17.8 |
| Number of cloudy days | 8 | 7 | 2 | 5 | 9 | 1 | 2 | 7 | 0 | 8 | 6 | 0 | 10 | 11 | 8 | 6.8 | 6.8 | 2.7 |
| Number partly-cloudy days | 10 | 10 | 13 | 9 | 6 | 15 | 12 | 8 | 2 | 10 | 4 | 0 | 7 | 9 | 8 | 9.6 | 9.6 | 9.5 |
| Number days dew | 16 | 16 | 10 | 8 | 19 | 18 | 15 | 20 | 16 | 19 | 26 | 4 | 10 | 22 | 21 | - | - | - |
| Mean monthly daily wind movement | 138 | 136 | 143 | 227 | 138 | 164 | 176 | 157 | 121 | 166 | 128 | 337 | 212 | 192 | 149 | 243 | 183 | 176 |
| Number days wind from south (include SE and SW) | 13 | 13 | 25 | 19 | 11 | 17 | 14 | 17 | 23 | 18 | 17 | 28 | 17 | 20 | 21 | 17.7 | 19.1 | 23.9 |
| Date on which first stem rust was observed | | 20 | | | 9 | | | 17 | | | 11 | | | 7 | | | | |
| Percentage of rust in 18 wheat varieties | | | | | | | | | | | | | | | | | | |
| Average-% | | 7 | | | 25 | | | 28 | | | 19 | | | 82 | | | | |
| Range -% | | 0 to 27 | | | 1 to 51 | | | 0 to 63 | | | 0 to 65 | | | 20 to 99 | | | | |

Table 2. Total daily wind run at Texas Substation No. 6, Denton, Texas, during April, May, and June, 1935 with comparisons with normal.

| Date | April |  | May |  | June |  |
|---|---|---|---|---|---|---|
|  | Total wind run | Direction | Total wind run | Direction | Total wind run | Direction |
| 1 | 157 | SE | 299 | SE | 176 | SE |
| 2 | 213 | NW | 192 | SW | 213 | SE |
| 3 | 276 | N | 248 | N | 142 | NE |
| 4 | 167 | SE | 387 | NE | 122 | NE |
| 5 | 240 | SE | 264 | NW | 96 | SE |
| 6 | 147 | NW | 58 | SE | 127 | SE |
| 7 | 405 | NW | 197 | SE | 148 | NE |
| 8 | 117 | SE | 227 | SE | 92 | NE |
| 9 | 285 | SE | 154 | SE | 117 | SE |
| 10 | 257 | NW | 162 | SE | 112 | SE |
| 11 | 371 | NW | 205 | SE | 63 | N |
| 12 | 344 | NW | 203 | SE | 99 | SE |
| 13 | 82 | SW | 230 | SE | 100 | SE |
| 14 | 248 | SW | 182 | SE | 136 | SE |
| 15 | 326 | NE | 200 | NE | 184 | SE |
| 16 | 107 | SE | 183 | NE | 294 | SE |
| 17 | 326 | SE | 191 | E | 253 | SW |
| 18 | 161 | SE | 185 | SE | 121 | NW |
| 19 | 273 | NW | 140 | SE | 64 | SE |
| 20 | 192 | NW | 83 | NW | 251 | S |
| 21 | 105 | SE | 161 | NW | 237 | E |
| 22 | 109 | SE | 87 | NE | 124 | NE |
| 23 | 218 | SE | 159 | NE | 108 | SE |
| 24 | 313 | SE | 179 | NE | 206 | SE |
| 25 | 186 | NE | 140 | SE | 244 | SW |
| 26 | 106 | NE | 208 | SE | 165 | NW |
| 27 | 49 | SE | 239 | SW | 76 | SE |
| 28 | 127 | SE | 246 | SE | 101 | SE |
| 29 | 276 | NW | 216 | SE | 124 | SE |
| 30 | 180 | SE | 160 | SE | 165 | SE |
| 31 |  |  | 163 | SE |  |  |
| Total | 6363 |  | 5948 |  | 4460 |  |
| Mean | 212 |  | 192 |  | 149 |  |
| 21-year mean | 227 |  | 184 |  | 175 |  |

As previously mentioned, it appears that the initial general infection must have taken place during the last week of April. As shown in Figure 3, both temperature and humidity were favorable during this period, and dew was present nearly every morning. Following this initial infection, the temperatures were not so favorable during the first week of May. On May 7 the first rust was observed and from that time supplied inoculum for spread of the disease. Following this initial appearance of the disease, environmental conditions were exceptionally favorable throughout the remainder of the growing season for development and spread of rust.

Wind Movement: Because of the importance of wind movement and direction in the spread of rust to other wheat-growing areas, no report of meteorological conditions would be complete without reference to wind movement. The total wind movement for each daily 24-hour period from April 1 to June 30 is given in Table 2.

Wind movement during April, May, and June was nearly normal; there were no great extremes, although there were several days when it was strong enough to carry rust spores long distances.

Previous to the initial general infection at Denton, Texas, fairly strong winds from the south occurred on April 5, 9, 19, and 24. Later in the season there were a number of days when the wind could easily have carried spores to states to the north of Texas and thus contribute to the national epidemic.

### Crop-Growth Factors Favoring Stem Rust Infection

The late maturity of the wheat crop in north Texas was one of the most important factors in the severity of the disease in the State and provided inoculum over a long period for spread to states to the north. In Table 3 dates of heading, date of ripening, and length of fruiting period are given for the years 1933 to 1935, inclusive, for the varieties of wheat grown in the field-plat variety tests at Denton.

Lateness of Heading: Date of first heading in 1935 was from 2 to 15 days later than in the spring of 1934, a fairly normal season. This late heading in 1935 resulted from a combination of several factors. Stands were thin as a result of winterkilling. The meteorological factors previously discussed, namely, excessive precipitation; cool, cloudy weather; and high humidity, combined with the thin stands, caused continued vegetative growth. The retarding effect of these factors was very evident in the manner in which the grain headed. Although wheat varieties normally reach full head in 3 to 5 days after first heads appear, in 1935 the plants were not fully headed until 8 to 13 days after

Table 3. Date of heading, date of ripening and length of fruiting period of winter-wheat varieties grown at Denton, Texas, 1933 to 1935, inclusive.

| Variety | T.S. No. | C.I. No. | 1933 Date First head | 1933 Date Fully ripe | 1933 Fruiting period, days | 1934 Date First head | 1934 Date Fully ripe | 1934 Fruiting period, days | 1935 Date First head | 1935 Date Fully ripe | 1935 Fruiting period, days |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Early blackhull | 15838 | 8858 | 4-27 | 5-30 | 33 | 4-24 | 6-1 | 38 | 4-29 | 6-3 | 35 |
| Quivira | 15833 | 8886 | 5-3 | 6-6 | 34 | 4-28 | 6-2 | 35 | 5-3 | 6-11 | 39 |
| Sutton | 15832 | 10053 | 5-12 | 6-8 | 27 | 5-7 | 6-6 | 30 | 5-14 | 6-17 | 34 |
| Denton | 9236 | 8265 | 5-9 | 6-8 | 30 | 5-5 | 6-6 | 32 | 5-16 | 6-17 | 32 |
| Mediterranean | 3015-81 | 10086 | 5-8 | 6-9 | 32 | 5-1 | 6-3 | 33 | 5-16 | 6-17 | 32 |
| Mediterranean | 3015-105-1 | 11587 | 5-8 | 6-7 | 30 | 5-2 | 6-2 | 31 | 5-11 | 6-14 | 34 |
| Mediterranean | 5933-20 | 10085 | 5-6 | 6-4 | 29 | 4-29 | 6-2 | 34 | 5-8 | 6-14 | 37 |
| Mediterranean | 5933-23 | 11525 | 5-6 | 6-6 | 31 | 5-2 | 6-4 | 33 | 5-11 | 6-14 | 34 |
| Mediterranean | 5933-34 | 11526 | 5-6 | 6-4 | 29 | 4-30 | 6-3 | 34 | 5-8 | 6-14 | 37 |
| Mediterranean | 5933-38 | - | 5-5 | 6-4 | 30 | 5-1 | 6-4 | 34 | 5-9 | 6-13 | 35 |
| Nebraska 60 | 15835 | 6250 | 5-12 | 6-10 | 29 | 5-9 | 6-9 | 31 | 5-14 | 6-17 | 34 |
| Kharkof | 16830 | 1442 | 5-12 | 6-9 | 28 | 5-9 | 6-9 | 31 | 5-13 | 6-18 | 36 |
| Blackhull | 7172 | 6251 | 5-9 | 6-7 | 29 | 5-7 | 6-7 | 31 | 5-12 | 6-15 | 34 |
| Kanred | 11763 | 5146 | 5-10 | 6-7 | 28 | 5-9 | 6-8 | 30 | 5-11 | 6-14 | 34 |
| Tenmarq | 12578 | 6936 | 5-8 | 6-7 | 30 | 5-7 | 6-6 | 30 | 5-10 | 6-15 | 36 |
| Fulcaster | 7082 | 6471 | 5-9 | 6-7 | 29 | 5-6 | 6-7 | 32 | 5-12 | 6-16 | 35 |
| Clarkan | 20400 | 8858 | 5-8 | 6-6 | 29 | 5-7 | 6-6 | 30 | 5-12 | 6-17 | 36 |
| Harvest Queen | 15837 | 6199 | 5-10 | 6-8 | 29 | 5-7 | 6-6 | 30 | 5-12 | 6-15 | 34 |
| Kawvale | 12577 | 8180 | 5-8 | 6-7 | 30 | 5-5 | 6-6 | 32 | 5-13 | 6-17 | 35 |
| Mean length of fruiting period | | | | | 30 | | | 32 | | | 35 |

the first heads emerged. The average date of first heading was about May 10, whereas the mean date of full heading was May 22, or 12 days later.

Delayed Maturity: As previously discussed, the excessive precipitation, high humidity, and cool temperatures continued throughout May and most of June. These conditions, together with thin stands, delayed the maturity of the grain. As shown in Table 3, the date of ripening in 1935 is in most instances 10 to 15 days later than in 1934. The wheat crop really did not mature even at this late date, but in most instances ripened because of rust damage. Harvest of small grains in the Denton area usually begins in late May and is nearly complete by June 10. In 1935 harvest of the experimental plots was not possible until June.

The above ecological conditions, which retarded the heading and ripening of the grain, were also favorable for the development of a stem-rust epidemic. The early infection and subsequent long period of development resulted in severe damage to the grain. The long period of development for rust was also a very important factor in the spread of rust to states to the north.

## Effect Of The 1935 Stem-Rust Epidemic On Wheat Yields

In Table 1 the date of first appearance of rust, the mean infection, and the range of infection at the end of the season for the years 1931 to 1935 are given. In years prior to 1935, stem rust was not a major factor in reducing yields excepting those of certain very susceptible varieties. Often stem rust does not reach its maximum until the crop is almost mature and in such years the infection may be fairly high, but the damage to the grain is relatively small. In 1935, however, the amount of initial inoculum apparently was great, and, as conditions were very favorable for spread from the time the first rust appeared, varieties were soon highly infected. Furthermore, the late maturity of the crop enabled the rust to develop and spread, while the host plants were in a very susceptible condition, resulting in severe damage to the host plants. Estimates of stem rust were made on two dates in 1935. The first reading was made on May 29 about a week after wheat had reached full head. The second reading was made near maturity. Agronomic data on rust infection, winter survival, yield of grain, and test weight of grain are given in Table 4.

Yield and plumpness of grain as indicated by test weight were closely associated in 1935 with early maturity and susceptibility to stem rust. Extremely susceptible varieties, such as Fulcaster, Harvest Queen, Sutton, and the Mediterranean strains, were highly infected with

Table 4. Yields and agronomic data for winter wheat varieties grown at Denton, Texas, 1935.

| Variety | T. S. No. | C.I. No. | Date first head | Estimated percent winter survival | Percent Rust Leaf | Percent Rust Stem 5-29 | Percent Rust Stem Maturity | Yield of grain Bu. per acre | Test weight lbs. |
|---|---|---|---|---|---|---|---|---|---|
| Early Blackhull | 15838 | 8856 | 4-29 | 42 | 58 | 3 | 20 | 14.1 | 55 |
| Quivira | 15833 | 8886 | 5-3 | 67 | 13 | 7 | 65 | 13.1 | 50 |
| Kanred | 11763 | 5146 | 5-11 | 82 | 75 | 7 | 60 | 8.8 | 45 |
| Kharkof | 16830 | 1442 | 5-13 | 90 | 85 | 9 | 90 | 8.7 | 44 |
| Mediterranean | 5933-20 | 10085 | 5-8 | 63 | 25 | 57 | 80 | 8.6 | 46 |
| Clarkan | 20400 | 8858 | 5-12 | 68 | 55 | 55 | 90 | 8.6 | 50 |
| Mediterranean | 5933-34 | 11526 | 5-6 | 57 | 13 | 68 | 80 | 8.3 | 43 |
| Mediterranean | 5933-38 | - | 5-9 | 48 | 6 | 78 | 90 | 8.0 | 46 |
| Kawvale | 12577 | 8180 | 5-13 | 50 | 4 | 20 | 80 | 7.6 | 40 |
| Turkey Selection | 20374 | 10016 | 5-9 | 78 | 99 | 8 | 85 | 6.9 | 46 |
| Blackhull | 7172 | 6251 | 5-12 | 58 | 70 | 15 | 75 | 6.9 | 48 |
| Tenmarq | 12578 | 6936 | 5-10 | 67 | 33 | 25 | 75 | 6.7 | 38 |
| Nebraska 60 | 15835 | 6250 | 5-14 | 83 | 90 | 32 | 90 | 5.0 | 46 |
| Fulcaster | 7082 | 6471 | 5-12 | 40 | 45 | 48 | 99 | 4.9 | 42 |
| Harvest Queen | 15837 | 6199 | 5-12 | 62 | 99 | 55 | 99 | 4.5 | 47 |
| Mediterranean | 5933-23 | 11525 | 5-11 | 47 | 6 | 85 | 99 | 4.5 | 44 |
| Mediterranean | 3015-105-1 | 11587 | 5-11 | 52 | 4 | 99 | 99 | 3.4 | 40 |
| Sutton | 15832 | 10053 | 5-14 | 40 | 38 | 58 | 99 | 3.4 | 41 |
| Denton | 9236 | 8265 | 5-16 | 32 | 13 | 40 | 99 | 2.7 | 39 |
| Mediterranean | 3015-81 | 10086 | 5-16 | 25 | 48 | 45 | 99 | 2.0 | 40 |

stem rust by May 29, or by the time they reached full head. The resulting yield was very low and test weight extremely low. Another factor that contributed to the low yield and late maturity of these strains was the lower survival. The thin stands not only retarded the development of the wheat plants, but also contributed to the low yield. The two early varieties, Early Blackhull and Quivira, were able to produce a fair yield of grain because of their ability to mature ahead of the severe rust epidemic. Kanred wheat showed some resistance to stem rust, at least in the early stages of the epidemic. Turkey Selection C.I. 10016 produced a low yield in spite of rather light stem rust infection and high winter survival. This was no doubt due to its extreme susceptibility to leaf rust.

## Conclusion

In conclusion, it should be stated that no one factor of weather or condition of the crop was responsible for the severe rust epidemic. All the factors studied contributed their respective parts and, because of the manner in which they were associated resulted in one of the most severe rust epidemics in history. These factors also played their parts in the spread of the disease to other wheat-growing areas. Had the acreage of wheat in north central Texas not been reduced by winter-killing, the loss would have been even more serious.

Under the existing conditions, which included thin stands; late maturity of the crop as a result of thin stands, excessive precipitation, and high humidity; favorable temperatures and humidity for rust development; frequent dews; cloudy weather; and favorable winds to carry the rust spores to other localities and states; the rust epidemic in Texas served as a source of inoculum for an extremely long period of time and thus contributed to the epidemic in other states.

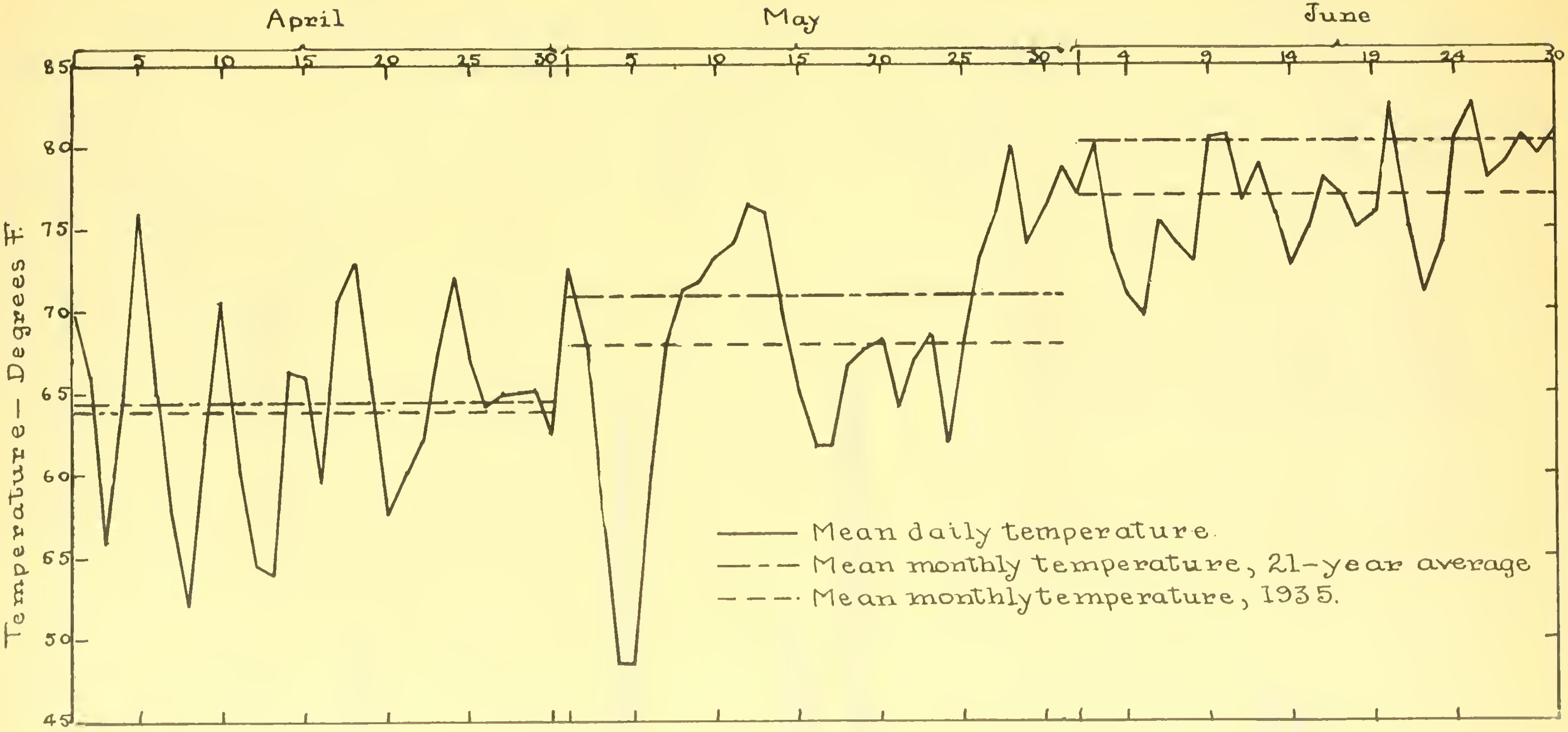

Figure 1 Mean daily temperatures, April, May, June, 1935, at Texas Substation No. 6, Denton, Texas.

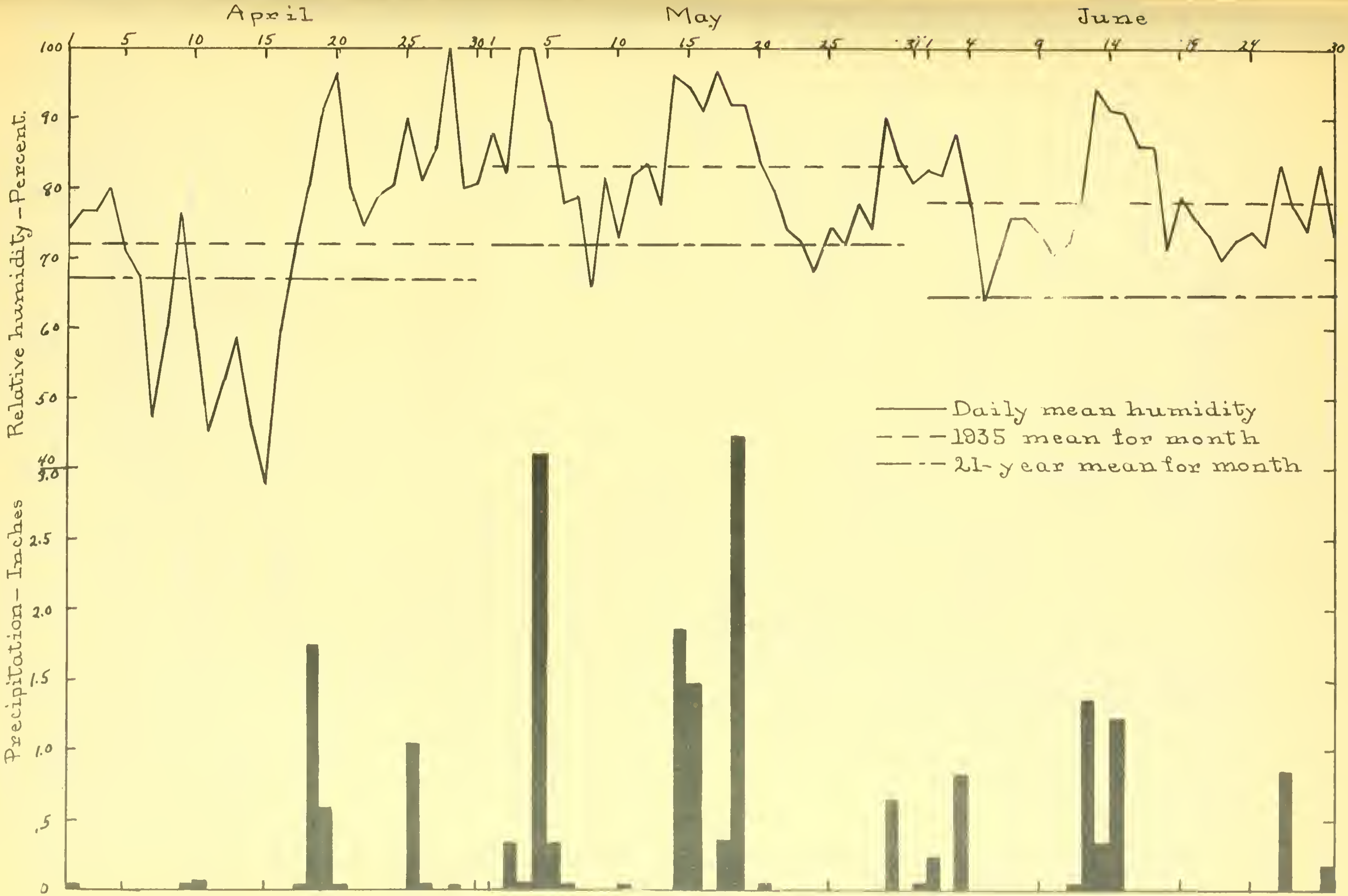

Figure 2. Mean daily relative humidity and precipitation, April, May, and June, 1935, at Substation No. 6, Denton, Texas

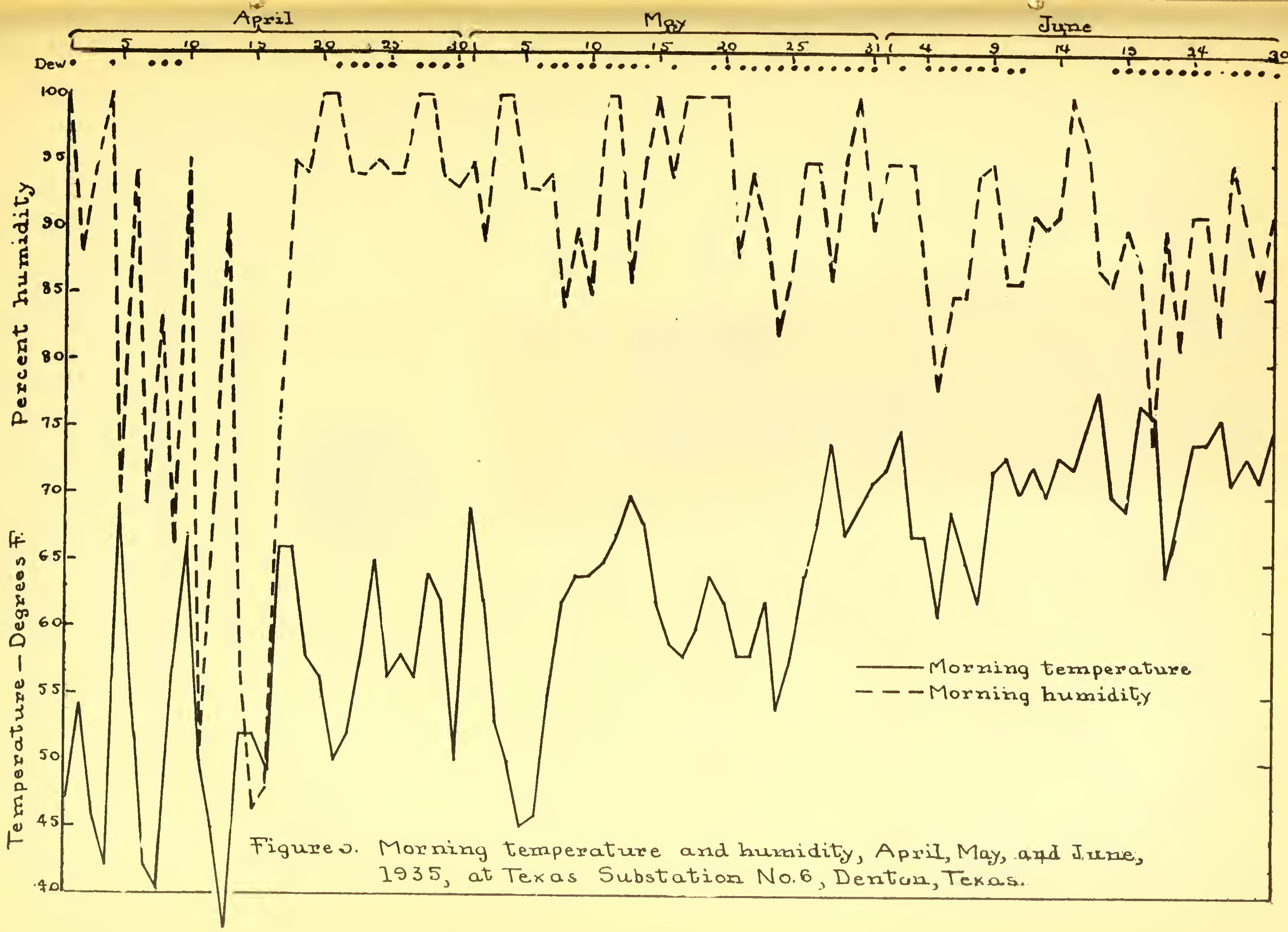

Figure 5. Morning temperature and humidity, April, May, and June, 1935, at Texas Substation No. 6, Denton, Texas.